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RADON LEVEL AND GAMMA RAY DOSE FROM COMMON BUILDING MATERIALS USED IN BASRAH SPORT CITY, BASRAH, IRAQ

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ABSTRACT

Most building materials of natural origin contain small amount of Naturally Occurring Radioactive Materials (NORM), mainly radionuclides from the ^{238}U and ^{232}Th decay chains. The natural radon gas concentration of most building materials used in the construction of Basrah Sport City (BSC), have been measured using the SSNTDs with RAD7 professional instrument radon monitor based on the alpha particle spectroscopy. Calibration factor for CR-39 track detector has been estimated using hybrid combination of both methods. Sodium Iodide NaI (Tl) gamma-ray detector has been used to measure the abundance of radium, thorium and potassium in the building materials used in the construction of BSC. Samples from soil, sand, gravel, cement, granite, marble and ceramic have been studied. In this study it is found that, building materials contain low levels of radon gas radioactivity and gamma dose rate within the average of other countries.

KEYWORDS: Radon, CR39, Calibration, RAD7, NaI, Building Materials

INTRODUCTION

Man is continuously exposed to ionizing radiation from Naturally Occurring Radioactive Materials (NORM). The origin of these materials is the Earth's crust, but they find their way into building materials. Radiation exposure due to building materials may be classified into external and internal exposures. It is well known that radiation exposure due to building materials in building is caused mostly by the external γ-rays and α-particles emitted from radio nuclides of the uranium (^{238}U) and thorium (^{232}Th) decay series as well as from the potassium radionuclide (^{40}K). The contribution of building materials to indoor radon and thoron concentration are usually low and can be measured by passive and active methods (Al-Jarallah et al, 2005, UNSCEAR, 2006, Liope, 2011, Misdaq et al., 2012, Xinwei Lu et al., 2012, Alzoubi et al., 2013, Saad et al., 2013). While the contribution of gamma, measured by either HPGe or NaI(Tl) detectors (Rizzo et al., 2001, Baykara et al., 2011, Xinwei et al, 2012 and Al-Suliati et al., 2012). To assess the radiological hazard to human health, it is important to study the radioactivity levels emitted by the building materials. There has been an increasing concern about exposure to Radon (^{222}Rn), Thoron (^{220}Rn) and their short lived decay products, they are recognized as the most important contributors to committed effective dose received by population due to the natural sources (Baykara et al, 2011).

Building materials are derived from both natural sources (e.g rock and soil) such as concrete, granite, marble and waste product such as (oil shale ash, waste from oil industry, waste from fertilizers) (Faheem et al., 2008).

In the present study, we used alpha spectroscopy to measure the alpha particles concentration emitted from natural sources in the building materials used in Basra Sport City (BSC), whereas for the radon measurement we used the SSNTD films and RAD7 instrument from DURRIDGE company Inc. USA. Several parameters have been estimated, including the calibration factor for tracks in CR-39 detector and radon exhalation rate, to evaluate the radiological risk associated with those building materials.

For the measurements of natural gamma activity, we used NaI(Tl) to evaluate the gamma radiation from natural sources in the building materials used in the construction of Basra Sport City.

MATERIALS AND METHODS

Samples

The samples investigated are commonly used building materials, which are; cement, granite, marble, ceramic, hollow brick, sand and raw materials used for building construction. The samples were homogenized and then dried in a temperature controlled furnace at 110^{o} C for 24 h to ensure that moisture was completely removed. Finally the dried samples were weighed and store in gas tight polyethylene plastic Marinelli Beaker, for about 30 days to ensure radioactive equilibrium between ^{226}Ra and ^{232}Th and their decay products. After that period, the samples were analyzed for natural radionuclide concentration using gamma-ray spectrometry. From each solid sample a 15x15 cm^2 piece was taken for radon exhalation measurements using solid state nuclear track detector CR-39 and RAD7.

The Active Radon Detector

A radon gas analyzer RAD7 was used to measure radon emanation from the ore samples. The ore sample was loaded into 2.6 l used as an emanation cylindrical container, shown in figure 1. The height of the container is 23 cm, to ensure radon detection only, was used as the radon accumulation chamber. The alpha RAD7 detector was operated in grab mode for 2 days protocol, with cycle 1h , recycle 48 and thoron off. The removable lid was equipped with two gas-tight tubes, one used to pump radon gas in RAD7 chamber (ZnS) and the other used to pump fresh air to the container. The system is a closed loop in which the gas circulates continuously. The experiment was performed at a relative humidity less than 10%, 18-25 ^{o}C and normal room atmospheric pressure (Hassan et al, 2011). After the sample is placed in the cylindrical container the filtered air decays inside the monitor chamber (ZnS), producing detectable alpha emitting progeny, particularly the Polonium isotopes. A high voltage of 2500 V is applied to the chamber walls.

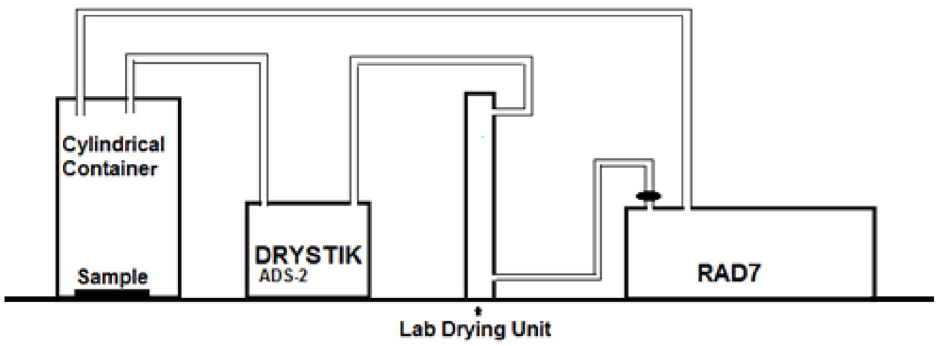

Figure 1: Schematic Diagram of Radon Measurement Using RAD7 Monitor

The solid state silicon detector converts alpha radiation directly to an electrical signal discriminating the electrical pulses generated by α-particles from the polonium isotopes (^{218}Po, ^{216}Po, ^{214}Po, ^{212}Po) with energies of 6.0, 6.7, 7.7 and 8.8 MeV, respectively. The measurement allows the simultaneous determination of ^{222}Rn exhalation rates that can be referred to the mass or the surface of the material. The concentration of radon emanated from each building materials sample inside the cylindrical container was allowed to build up with time and it was measured in 1h cycle for an average time of 48h. The build-up radon activity inside the emanation container follows the equation

$$C_t = C_o\left(1 - e^{-\lambda T}\right) \tag{1}$$

where C_t is the concentration at time T, λ is the decay constant of the nuclide concerned and C_o is the final value

of the activity at t≈ $7.2T_{1/2}$, which approximately 27.5 days for radon.

The Passive Radon Technique

Radon exhalation rate was measured using the solid state nuclear track detector SSNTD type CR39. The cylindrical can technique was used for long term measurement of radon concentration rate. In this technique, CR39 of dimension 1.5x1.5 cm^2 was fixed with double sides adhesive tape to the top bottom of the container as shown in figure 2 (Shweikani et al, 2009). The sample area was covered with a 5 mm thickness of soft sponge to prevent thoron from reaching the detector. The fixed cans were isolated by cold silicon to prevent the radon diffusion in or out of the can. The exposure time was 90 days in constant temperature. At the end of this time, the detectors were removed and chemically etched with 6.25 N NaOH at 70±1 ^{o}C for seven hours to observe tracks. The tracks were counted using an optical microscope with suitable magnification. To translate the number of counted tracks into radon concentrations, a calibration made by using a combination of both active and passive methods, as will be shown in the next section.

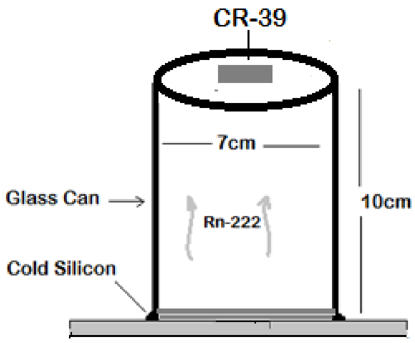

Figure 2: Schematic Daigram for Radon Chamber Fixed on Marble Sample for the Passive Measuremnt

The Calibration Factor

Calibration factors are the quantities, which are used for converting the observed track density on SSNTD after etching to the activity concentrations of the species of interest. If ρ denotes the track densities in ($Track/cm^2$. day) observed on a SSNTD due to exposure in a given mode to a concentration C in Bq/m^3 of given species for a time T, it is obvious that

$$\rho = kCT \tag{2}$$

Where, we define k as the calibration factor. In the can mode, only radon emanate in the can and the progeny species from the environment will be prevented

In this study, we used a hybrid method between active and passive modes to calibrate the CR-39 track detectors. In this method, the standard solid ^{226}Ra source (185 kBq) was used (Saad, 2008). The disk type source was placed in the cylindrical grove on metal plate made for this purpose shown in figure 3. Two CR39, 1.5x1.5 cm^2, detectors were fixed with double sides adhesive tape to the top bottom of the the can. The average tracks number for 10 fields in each detector were recorded by microscope and the average of two detectors were calculated as well. The experiment was repeated for different irradiation time (2, 4, 8, 12, 24, 48) hours to get a good statistic. The calibration curve is produced and presented in figure 4, with very good correlation (r = 0.985) between radon concentrations recorded by RAD7 and track density.

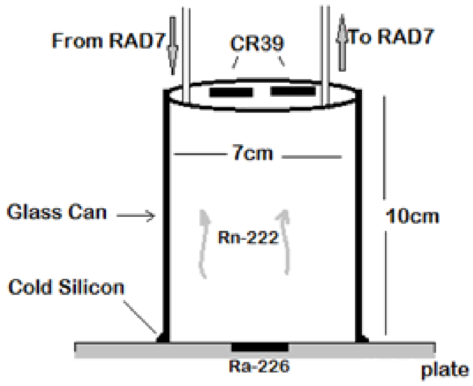

Figure 3: The CR39 Calibration Experiment Setup

The calibration factor for CR39 polymeric detectors using the hybrid technique between SSNTDs and RAD7 is 0.1245±0.0093 $\frac{T}{cm^2.d}$ $per\ 1\ Bq\ m^{-3}$

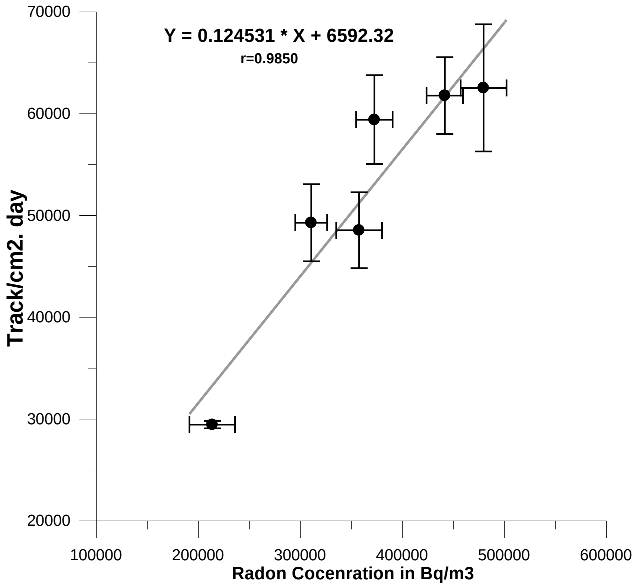

Figure 4: The Calibration Curve for CR-39 Detector Used in this Experiment

RADON EXHALATION RATE

At the equilibrium state, the final activity of radon exhaled from each sample inside the can is given by (Durrani et al, 1997)

$$E_{ex} = \frac{CV\lambda/A}{T+(e^{-\lambda T}-1)/\lambda} \tag{3}$$

where E_{ex} is exhalation rate in unit Bq $m^{-2}.d^{-1}$, C is integrated exposure measured by the detector in unit Bq m^{-3} day, λ is radon decay constant, T, the exposure time, V the volume of the can and A is the surface area covered by the can.

RESULTS AND DISCUSSIONS OF RADON EMANATION

In Table 1, we summarized the average value of radon activity concentration from different construction materials used in BSC. The analysis of collected data shows that, the Spanish Ceramic is always less activity than the Turkish Marbles and Granite. This could be due to the manufacturing techniques of the ceramic which has glass type face, which reduce the radon exhalation. Radon activities were found to vary from 243 ± 33 Bq/m^3 for Spainish ceramic to 4429 ± 251 Bq/m^3 for local sand. Last column in table 1, shows the radon exhalation rate from all the building materials used in the

present work. From this table one can see that, soil, cemented bricks, gravel, sand and cement are always greater than the other building material samples. The maximum radon exhalation found was from local sand (3.682±0.223 Bq/m^2. d) which is less than the Pakistani sand (4.64 Bq/m^2.d) as one can see from table 2. The minimum is observed in the sample of ceramic (0.202 ± 0.028 Bq/m^2. d). Average radon exhalation from samples of granite, marble and ceramic are found to be (0.321 ± 0.043 Bq/m^2. d), (0.370 ± 0.035 Bq/m^2. d), (0.279 ± 0.027 Bq/m^2. d) respectively. In order to compare the results obtained from the present work, with the works of other researchers on the same type of building materials, we represent Table 2 which is taken from references (Matiullah, 2008, Chen et al, 2010 and references sited there). In column 4, the results of the present work are shown, which look within the average of the world, recommended by (UNSEAR).

Table 1: Radon Concentration and Exhalation Rate from Building Material Used in BSC

Sample Type and Origin	Radon Concentration Passive Method in (Bq/M^3)	Radon Concentration Active Method in (Bq/M^3)	Arithmetic Average of Radon Concentration (Bq/M^3)	Radon Exhalation Rate in (Bq/M^2.D)
Granite- Turkish	369 ± 28	409 ± 73	389 ± 50	0.324 ± 0.042
Granite -Turkish	403 ± 30	483 ± 72	443 ± 51	0.317 ± 0.043
Marble- Turkish	388 ± 29	425 ± 55	407 ± 42	0.339 ± 0.036
Marble- Turkish	296 ± 22	392 ± 55	344 ± 39	0.287 ± 0.033
Marble- Turkish	486 ± 37	520 ± 57	503 ± 47	0.419 ± 0.041
Marble- Turkish	330 ± 25	361 ± 40	346 ± 32	0.288 ± 0.028
Marble- Turkish	381 ± 28	432 ± 61	407 ± 45	0.232 ± 0.039
Ceramic- Spain	218 ± 16	304 ± 43	261 ± 30	0.217 ± 0.026
Ceramic-Spain	243 ± 18	314 ± 50	278 ± 33	0.339 ± 0.028
Ceramic-Spain	205 ± 15	282 ± 51	243 ± 33	0.202 ± 0.028
Ceramic-Spain	216 ± 16	344 ± 34	280 ± 25	0.372 ± 0.022
Ceramic-Spain	260 ± 20	378 ± 57	319 ± 38	0.266 ± 0.032
Brick-locally	2101 ± 158	1795 ± 68	1897 ± 112	1.581 ± 0.109
Gravel- locally	1436 ± 108	1357 ± 68	1396 ± 88	1.164 ± 0.079
Sand- locally	4214 ± 316	4629 ± 185	4429 ± 251	3.682 ± 0.223
Soil- locally	3350 ± 251	3917 ± 235	3633 ± 243	3.026 ± 0.217
Cement- Pakistan	2891 ± 217	3045 ± 152	2968 ± 185	2.509 ± 0.167

Table 2: Radon Exhalation Rate from Various Countries in Comparison with the Present Results

Country	Material	Range of Value in Bq/m^2. d	Average Values of Present Work in Bq/m^2. d
Pakistan	Soil	11.58	Soil=3.026
	Sand	4.64	Sand=3.682
	Bricks	5.08	Brick=1.581
	Marble	7.08	Marble= 0.313
	Cement	5.5	Cement=2.509
Saudi-Arabia	Granit	2.88-3144	Granit=0.324
Syria	Soil	1728-777600	Ceramic=0.339
Morocco	Soil	0.072-3.48	
Algeria	Marble	0.84-1.584	
	Brick	1.872-2.808	
	Cement	1.992-3.36	
	Granite	1.128-2.136	
Egypt	Cement	61.176-181.3	
India	Soil	2.904-26.4	
Canada	Marble	0.1-0.4	
	Ceramic	0.2-2.2	
	Porcelain	0.5-1.4	
World average	Soil	2.0-13.82(UNSEAR)	

The Indoor Effective Dose Rate

In order to estimate the annual indoor effective dose due to the building and finishing materials, one has to take into account the conversion factor from activity concentration to effective dose. In the UNSCREAR 2000 report, the value of $\frac{9x10^{-6} mSv}{h}$ $per\ 1Bq/m^3$ was found. Hence, the indoor effective dose rate in unit of mSv/y can be calculated, by the following relation

$$H_{in} = C_{Rn} . F . T . D \tag{4}$$

where C_{Rn} is the measured radon concentration in Bq/m^3, F is the radon equilibrium factor indoor (0.4), T is the indoor occupation time (2190 h/y) and D is the conversion factor. The annual indoor effective dose from the corresponding measurement radon concentration has been calculated using equation (4), which varies from (1.92 to 3.97) mSv/y for finishing materials. The average annual effective dose, from radon gas emanation, for other construction building materials is 9.33 mSv/y.

Mass Concentration of Radon

The radon concentration per unit mass of building material can be written as (Saad, 2008);

$$C_m = \frac{C_{Rn}\, V}{m} \text{ Bq/kg} \tag{5}$$

where m is the mass of the sample and V is the volume on animator.

In these calculations, the range of radon concentration from building materials, in mass unit, found to be ranged from 2.59 ±0.35 Bq/kg to 17.44±2.30 Bq/kg, with average value 7.68 Bq/kg as shown in Table 3.

Table 3: Radon Concentration per Unite Mass

Sample Number	Sample Type and Origin	Arithmetic Average of Radon Concentration	Radon Concentration in (Bq/Kg)
1	Granite- Turkish	389±50	2.59 ±0.35
2	Granite - Turkish	443±51	3.29±0.40
3	Marble- Turkish	407±42	6.22±0.69
4	Marble- Turkish	344±39	5.59±0.67
5	Marble- Turkish	503±47	7.26±0.73
6	Marble- Turkish	346±32	5.62±0.56
7	Marble- Turkish	407±45	6.22±0.73
8	Ceramic- Spain	261±30	6.16±0.75
9	Ceramic-Spain	278±33	7.22±0.90
10	Ceramic-Spain	243±33	4.21±0.59
11	Ceramic-Spain	280±25	4.85±0.47
12	Ceramic-Spain	319±38	4.87±0.61
13	Brick-locally	1897±112	12.97±0.91
14	Gravel- locally	1396±88	10.05±0.74
15	Sand- locally	4429±251	17.44±2.30
16	Soil- locally	3633±243	14.31±2.50
17	Cement- Pakistan	2968±185	11.69±0.86

GAMMA RAY MEASUREMENTS

Gamma ray spectroscopic system consist of a 3" x 3" NaI(Tl) well type detector (ORTEC company USA), which was housed in a cylindrical lead shield of about 80 cm length and 25 cm diameter. The lead shield thickness was about 3.5 cm and this is suitable for limiting the gamma background. The energy calibration was performed by using ^{137}Cs peak at

662 keV and two peaks of ^{60}Co with energy 1172.6 keV and 1332.8 keV respectively. The counting time for each sample was about 28800 s. In addition, the background levels of laboratory were surely found prior to the whole period of each sample measurement.

The activity concentrations were calculated using the following equation (Baykara et al, 2011);

$$A\left(\frac{Bq}{kg}\right) = \frac{NC}{\varepsilon\, I_\gamma\, T\, M} \tag{6}$$

Where NC is the net count under the peak (count per second), ε is the detector efficiency of specific γ ray, I_γ is gamma decay branching ratio, T is the counting time in second and M is the mass of the sample (kg). The gamma ray energies of 186.0 keV, 351.9 keV, 609.3 keV and 1764.5 keV were used to determine the concentration of ^{226}Ra. Gamma ray energies 238.4 keV, 538.3 keV, 911.1 keV, 968.9 keV were used to determine the concentration of ^{238}Th. The activity of ^{238}U was determined by gamma energies 1001 keV and 1120 keV. The 1460.7 keV gamma-ray of ^{40}K determined the concentration of ^{40}K. The activity concentration A(Bq/kg) of each nuclei together with their corresponding total uncertainty were calculated and listed in Table 4.

It may be seen from the table that the activity concentration of ^{226}Ra ranged from 9.24 to 254.14 Bq/kg with average 122.87 Bq/kg. While for ^{232}Th and ^{238}U from 3.38 to 36.27, average 21.67 Bq/kg, 4.5 to 96.38, average 46.09 Bq/kg respectively. The highest activity concentration level for ^{40}K was 750.25 Bq/kg and the minimum value was 7.95 Bq/kg, with an average of 362.97 Bq/kg. These results were found to be within the average of other material manufactured in different countries (Otoo et al.) In order to check the correlation between the radon gas concentration in Bq/kg and the ^{226}Ra (parent of radon), a correlation plot has been produced and presented in figure 5. The fitted line shows a good correlation between them.

Table 4: Gamma Ray Concentration in the Unit of Bq/Kg for the Building Materials Used in the BSC

Sample Type and Origin	^{226}Ra	^{232}Th	^{238}U	^{40}K
Granite- Turkish	137.12 ± 6.86	36.27± 1.81	65.05±32.52	449.47±22.47
Granite - Turkish	23.30 ± 0.32	8.79 ± 0.12	42.45±10.61	93.44±1.26
Marble- Turkish	101.07± 3.37	23.83 ± 0.79	57.82±9.63	373.07±12.43
Marble- Turkish	120.17 ± 6.70	34.98 ± 1.94	92.30±11.54	750.25±41.68
Marble- Turkish	74.87 ± 7.46	22.63 ± 2.26	18.51±1.85	453.87±45.39
Marble- Turkish	79.09 ± 1.78	9.92 ± 0.22	39.03±3.25	180.63±3.92
Marble- Turkish	48.59 ± 12.15	18.18± 4.54	5.07±0.36	125.55±31.38
Ceramic- Spain	73.26 ± 2.15	28.75 ± 0.85	65.18±4.07	372.14±10.95
Ceramic-Spain	102.25 ±2.84	29.79 ± 0.83	96.38±5.35	523.75±14.55
Ceramic-Spain	76.72 ± 1.75	18.69 ± 0.42	74.35±3.73	500.75±11.38
Ceramic-Spain	112.56 ± 4.68	35.89 ± 1.49	69.72±3.17	306.00±12.75
Ceramic-Spain	9.24 ± 0.51	3.38 ± 0.19	5.43 ±0.22	38.74±2.14
Brick-locally	195.03 ± 5.94	26.14 ± 1.63	35.52±1,36	377.40±23.59
Gravel- locally	174.42 ± 6.91	28.60 ± 1.59	75.37±2.69	667.95±37.11
Sand- locally	254.14 ± 3.87	5.97 ± 0.43	18.42±0.61	142.07±10.14
Soil- locally	178.46± 13.07	7.24 ± 1.20	18.50±0.58	560.29±93.38
Cement- Pakistan	197.30 ± 4.24	29.33 ± 0.98	4.50±0.13	696.78±23.23

The values of emanated radon from samples per unit mass, from Table 3, were matched against the radium concentration of 17 samples, from Table 4, as shown in figure 5. The solid line in the figure shows good linear correlation between radium and radon emanation with correlation coefficient (R= 0.825). However the measured radium concentrations are associated with trapped radon in the sample, since the untrapped radon was emanated and measured.

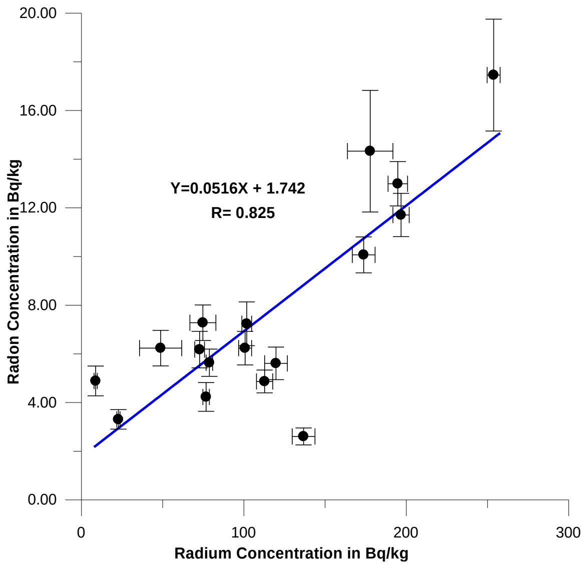

Figure 5: The Correlation between Emanated Radon and Radium Content in Unit of Bq/kg

Calculation of Radium Equivalent

Radium equivalent activity (Ra_{eq}) is used to assess hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg which is, determined by assuming that 370 Bq/kg of ^{226}Ra or 260 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produce the same γ dose rate. The Ra_{eq} of a sample in (Bq/kg) can be achieve using the following relation (Baykara et al, 2011);

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \tag{7}$$

The radium equivalent activities of samples under investigation were calculated on the basis of the above equation and are shown in Table 5. For all samples, the radium equivalent values ranging from 1.42 Bq/kg to 38.65 Bq/kg with arithmetic average 15.33 Bq/kg and this is less than recommended international value 370 Bq/kg.

Internal Hazard Index

Radon short lived products are hazardous to the respiratory organs for people living or working inside. The internal hazard index defined as (Berertka et al, 1985)

$$H_{in}\left(\frac{Bq}{kg}\right) = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \tag{8}$$

For the safe use of building materials in the construction of dwellings, H_{in} must be less than unity. The calculated values of internal hazard of samples under investigation, shown in table 5, range from 0.071 to 0.98, with average 0.662 Bq/kg. This indicates that gamma activity in the building materials used in the construction, do not exceed the proposed criterion level.

Calculation of Absorbed Dose Rate in Air

The absorbed dose rates in air due to gamma ray emission from building material are calculated from ^{238}U, ^{232}Th and ^{40}K concentrations in materials. The equation used in this calculation is;

$$D\left(\frac{nGy}{h}\right) = 0.430A_{U} + 0.666\ A_{Th} + 0.042A_{K} \tag{9}$$

This parameter used to assess the radiological hazard due to gamma radiation from building materials to

residence. The results of calculations of this parameter, table 5, show an average value of 132.75 nGy/h, maximum value 209.05 nGy/h and minimum value 15.32 nGy/h. In the UNSCEAR (2000), a value of 0.7 Sv Gy^{-1} was used for conversion coefficient from absorbed dose in air to effective dose received by adults. The annual exposure time assumed as 2190 h y^{-1}, where 0.25 is the indoor occupancy factor. The calculated values of the annual effective dose in air due to the building material used in the BSC, range from 0.023 to 0.32 mSv y^{-1}. The average annual effective dose, 0.203 mSv y^{-1}, is within the reference range 0.3-1.0 mSv y^{-1}, given by Tzortzis et al. 2003.

Table 5: The Radium Equivalent, Internal Hazard Index and Absorbed Dose Rate for Building Materials under Investigation

Sample Type and Origin	Ra_{eq} (Bq/Kg)	H_{in} (Bq/Kg)	D($\frac{nGy}{h}$)
Granite- Turkish	38.65±1.93	0.98	202.02
Granite - Turkish	11.94±0.16	0.17	38.58
Marble- Turkish	16.88±0.56	0.71	149.05
Marble- Turkish	24.45±1.35	0.94	209.05
Marble- Turkish	9.18±0.92	0.58	130.05
Marble- Turkish	3.62±0.08	0.50	98.14
Marble- Turkish	15.97±3.99	0.35	74.76
Ceramic- Spain	16.12±0.47	0.58	128.79
Ceramic-Spain	21.70±0.60	0.77	168.74
Ceramic-Spain	13.81±0.31	0.59	131.21
Ceramic-Spain	12.42±0.52	0.81	167.51
Ceramic-Spain	2.04±0.11	0.07	15.32
Brick-locally	14.16±0.89	0.69	146.38
Gravel- locally	13.79±0.77	0.92	199.36
Sand- locally	1.42±0.10	0.35	67.73
Soil- locally	25.73±4.29	0.56	124.97
Cement- Pakistan	18.77±0.62	0.94	205.12

CONCLUSIONS

Radon activity concentration, radon exhalation rate and gamma ray concentration from the building materials used in the construction of BSC, were determined. Detector calibration factor has been found using a hybrid radon detection system combining electronic radon gas counter RAD7 and dosimeter based on CR-39. It was found that radon concentration from finishing building materials varied between 243 Bq/m^3 to 508 Bq/m^3 and radon exhalation 0.202 Bq/m^2.d to 0.418 Bq/m^2.d, while these factors in the raw material vary from 1396 Bq/m^3 to 4429 Bq/m^3 and radon exhalation 1.164 Bq/m^2.d to 3.682 Bq/m^2.d. The radon exhalation rate of all samples has been found to be in the range of the world average value (2.0-13.8 Bq/m^2.d). Hence one can conclude that these materials and their ores may be used for construction purposes in the BSC, as they do not pose any health hazards due to radon exhalation. The natural gamma activity level of building material have been measured using NaI(Tl) gamma-ray spectrometer. The radium equivalent rate, internal hazard index, the indoor absorbed dose rate and the corresponding annual dose were evaluated. The results show that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in all investigated samples are in the range of the other countries. The range of radium equivalent values were 1.42 to 38.65 Bq/kg, which is much less than the recommended international value 370 Bq/kg. The calculated annual effective dose from all building materials was 0.203 mSv y^{-1}, which is less than the recommended total effective dose 2.5 mSv/y. The study shows most of building materials used in the construction of BSC do not pose any significant source of radiation hazard and are safe used in the construction.

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